

White Paper on Trunking Allocation Standards

Part 90 Spectrum between 150 and 470 MHz

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in response to requests from

Public Safety Communications Council

Land Mobile Communications Council

and to the Second Further Notice of Proposed Rulemaking in FCC Dockets 10-36
and 07-100

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(Note: nothing in this document is necessarily endorsed by LMCC or PSCC)



Trunking, a term borrowed from the telephone system, allows sharing of limited channels by assigning all channels to each radio allowing each subsequent channel to be used only when the prior one is busy. It is the basis of cellular service and will remain the most spectrum efficient technology until it is replaced by IP-based "smart" radios. Even then, dependable and interference-free service areas for radio channels will be necessary.

The 47 FR §90.187 Rule establishing protected service areas (PSA's), rather than "shared spectrum" for PLMR licensees in Part 90 below 470 MHz needs revision, as it has three major flaws:

- 1) Its assumptions allowing interference to less spectrum-efficient technologies did not correctly anticipate the current progress in narrowbanding;
- 2) It does not fully define protections after the fact, i. e., when new applicants must protect incumbent trunked licensees; and
- 3) There is no explicit method to protect or allocate mobile-only systems in the vicinity of trunked operations.

In order to clarify these issues, and in the light of new "super-narrowband" digital technologies such as NXDN and DMR ("MotoTRBO"), an example is presented and analyzed in detail. This should allow commenters and regulators alike to balance the need for clear and consistent standard allocation methods against spectrum efficiency and the fostering of new technology.

The same issues arise for Public Safety outside of trunking in most cases, as PSA's are also required, and in other bands such as the UHF TV sharing band (470-512 MHz) and the 700/800 bands, where several approaches to better spectral density are accepted by FCC, and to a pending Petition assigning interstitial 12.5 kHz channels between 854 and 861 MHz. Lastly, in other cases outside of Public Safety where protected service is desired and trunking is not contemplated, the principles here proposed apply--as an example, consider the effort now underway to convert the VHF railroad spectrum to 6.25 kHz channels and apply locomotive radio remote control, a clear application for spectrally efficient PSA's.

For those unfamiliar with §90.187 it is appended as Appendix A.

A general examination of allocation policy must ask three questions:

- 1) What area is protected?
- 2) How to calculate interference?
- 3) What standard should protect mobile transmitters (uplink), in mobile-only and repeater systems?

Since our illustrative example is a UHF system, the references to protection use UHF defaults--these can be substituted with VHF defaults.

Protected Area

The two published methods for defining a protected area are the FCC Rules and the TIA/EIA Technical Service Bulletin 88 ("TSB-88"), both of which are defined over outbound (base-to-mobile) paths only. The Rules describe a statistical approximated polygon (contour) based on averaged terrain, while TSB-88 uses real terrain and analyzes a tile-based grid in various ways. We here recommend a combination of the two to define protection.

In preparing this paper, a common assumption was used: that the FCC defined service contours (at UHF, 39 dB μ V/m) limit protection, and within those contours, when applying TSB-88, only tiles which actually receive that field or better are protected. This assumption results in cases of both too much and too little protection. The most obvious case, which resulted in an agreement among PSCC coordinators in 2008, concerns interference in and protection of an area which is of no interest to the operator, such as outside a County or State Boundary, over water &c. However, for several of the incumbents in this study, coverage is desired not only outside the County boundary, but well outside the 39 dB μ V/m contour as well. In typical Industrial/Business trunked systems, such jurisdictional boundaries don't apply at all. We thus consider and analyze all three cases--limiting by the base station contour, limiting by a County Boundary and limiting by noise floor (approximately 20 dB μ V/m at UHF). Our recommendation is to limit protection to geographic boundaries where appropriate, and not to protect service outside the traditional base station contours. The salient PSCC agreement calls for protection "to the base station contour, the administrative boundary or the mobile area of operation, whichever is least in any direction." To enable protection of only the desired area, a new data element could be added to the regulatory data, so that a business licensee could specify whether it desired multistate service, a city public safety licensee could indicate that it services the entire county or counties nearby &c. This data should be computer-parseable.

Our Example

Logan County, KY recently requested a single site eight channel centralized trunking (FB8) system in the Public Safety frequency pool, for which there is insufficient traditional narrowband spectrum (12.5 kHz channel bandwidth). Consequently, the applicant requested NXDN protocol (6.25 kHz channel bandwidth, 4.0 kHz occupied bandwidth) in the UHF band. According to LMCC agreements, these channels must protect adjacent incumbents (spaced by frequency center at 6.25 kHz) from contour overlap in both directions between the 39 dB μ V/m F(50,50) service and F(50,10) 29 dB μ V/m interference contours. However, no channels could be found which meet even those criteria. We posted a series of plots of nine candidate frequencies in PDF format at

http://radiosoft.com/Logan/Logan_Contours.pdf

All records having separation of less than 15 kilometers between contours in either direction (caused and received) are shown. There were no incumbent protected mobile-only systems found for this applicant.

Note that this application does not necessarily represent any current action pending at FCC--it is discussed here only as an illustration.

How to Calculate Outbound Interference

Since the publication of TSB-88 in 1998, no better standard has been proposed, while TSB-88 has been continuously updated with new equipment profiles and modulation types. We propose, in this example, that some of the candidate frequencies could be licensed despite contour overlaps, some could be licensed with some interference to the proponent, and one frequency would cause unacceptable interference, regardless of various protection assumptions, and would require concurrence from at least one incumbent.

TSB-88 describes several methods for modeling interference, and several variations of calculation parameters which depend, among other things, on the desired Delivered Audio Quality ("DAQ"). The TSB-88 method of statistically modeling degradation of reliability in the presence of interference ("Area Reliability Degradation", or ARD) distributes the failing tiles, is more permissive, cannot easily be geographically represented and is not used here--rather, we use TSB-88 to determine pass/fail for each subject protected tile, and assess the failing tiles against the entire pool of protected tiles to derive a percentage of interference. We have chosen to use a tile size of 30 arc seconds (close to 90 meters at US latitudes), and a DAQ of 3.0. Other assumptions, varying tile size and DAQ, are given in appendix B, but the results are unremarkable.

The contour overlaps and actual interference predicted by TSB-88.C in both directions within the 39 dB contours is given in Table 1. In all cases, the frequency spacing from incumbents was found to be 6.25 kHz, so all contour overlaps were calculated as above with 39/29 dB μ V/m. Since no overlap is understood to be permitted, all negative contour clearance numbers (CLR from the proponent and CLR to the

proponent) are highlighted in pink. There is at least one such overlap both caused and received for each proposed frequency, so by the LMCC method all proposed frequencies fail.

To model the actual likelihood of interference in the outbound case (as received by mobiles), TSB-88.C was used, with the latest published data for the various modulation types in use. Some assumptions were made, as one must infer modulation type from the licensed emission designator. In all cases where the emission designator showed 16 kHz or 20 kHz, wideband analog modulation was used (AFM 5, referring to 5 kHz deviation), and where 11k3F3E was shown, narrowband analog was used (AFM 2.5). The cases where interference caused to the proponent by multiple radios exceeded 5% are highlighted in yellow, and the cases where interference from either the proponent or incumbent exceeded 5% is in red.

Proposed			Incumbent						TSB-88C: DAQ = 3.0		Contour Overlap Clearance (LMCC Method)		
Frequency	Modulation	Ix Rec.	Callsign	Frequency	Modulation	Class	ΔF [kHz]	Dist. [km]	Ix To Proposed	Ix To Existing	Clr From	Clr To	Clr Total
453.19375	NXDN	0	WQHA642	453.1875	AFM 2.5	FB2	6.25	53.16	0	0	1.24	0.73	-5.96
453.19375	NXDN	0	WPZK721	453.2	AFM 2.5	FB8	6.25	50.46	0	0.11	-5.84	-5.96	-5.96
453.19375	NXDN	0	WQDP576	453.2	AFM 2.5	FB8	6.25	54.42	0	0	6.98	3.2	-5.96
453.26875	NXDN	0.21	WPSG835	453.2625	AFM 2.5	FB2	6.25	60.87	0	0	-13.34	-10.51	-13.34
453.26875	NXDN	0.21	WPSG835	453.2625	C4FM	FB2	6.25	60.87	0	0	-13.34	-10.51	-13.34
453.26875	NXDN	0.21	WPSG835	453.2625	EDACS-NB	FB2	6.25	60.87	0	0	-13.34	-10.51	-13.34
453.26875	NXDN	0.21	KEL335	453.275	EDACS-NB	FB2	6.25	69.36	0	0	16.7	14.08	-13.34
453.34375	NXDN	0.21	WPSG835	453.3375	AFM 2.5	FB2	6.25	60.87	0	0	-13.34	-10.51	-13.34
453.34375	NXDN	0.21	WPSG835	453.3375	C4FM	FB2	6.25	60.87	0.05	0	-13.34	-10.51	-13.34
453.34375	NXDN	0.21	WPSG835	453.3375	EDACS-NB	FB2	6.25	60.87	0	0	-13.34	-10.51	-13.34
453.34375	NXDN	0.21	KJQ831	453.35	AFM 5	FB	6.25	50.12	0	3.68	12	2.95	-13.34
453.34375	NXDN	0.21	KJQ831	453.35	AFM 5	FB2	6.25	48.28	0	0.94	4.37	-2.21	-13.34
453.34375	NXDN	0.21	WQA711	453.35	AFM 5	FB2	6.25	75.19	0	0.19	14.16	14.02	-13.34
453.34375	NXDN	0.21	WQDP576	453.35	AFM 2.5	FB8	6.25	52.3	0	0	1.73	-1.2	-13.34
453.39375	NXDN	7.99	WPQD283	453.3875	AFM 2.5	FB2	6.25	43.5	0	0.91	-16.39	-16.95	-24.89
453.39375	NXDN	7.99	KCQ735	453.3875	AFM 2.5	FB2	6.25	50.9	0.41	0.16	-24.89	-20.72	-24.89

453.39375	NXDN	7.99	WQD432	453.4	AFM 5	FB	6.25	41.92	4.9	3.97	-13.8	-12.68	-24.89
453.39375	NXDN	7.99	WPNX520	453.4	AFM 5	FB8C	6.25	49.86	2.37	6.03	-14.34	-13.67	-24.89
453.53125	NXDN	0.83	KIM774	453.525	AFM 5	FB2	6.25	55.74	0.77	6.23	-12.38	-9.52	-13.34
453.53125	NXDN	0.83	WQDP576	453.525	AFM 2.5	FB8	6.25	54.42	0	0	6.98	3.20	-13.34
453.53125	NXDN	0.83	WPSG835	453.5375	AFM 2.5	FB2	6.25	60.87	0.03	0.04	-13.34	-10.51	-13.34
453.59375	NXDN	0.26	WPWS449	453.5875	AFM 2.5	FB2	6.25	36.38	0	1.15	-1.8	-10.91	-10.91
453.59375	NXDN	0.26	KDX279	453.6	AFM 5	FB	6.25	73.7	0	0.12	-1.86	1.44	-10.91
453.59375	NXDN	0.26	KDX279	453.6	AFM 5	FB2	6.25	73.7	0	0.12	-1.86	1.44	-10.91
453.59375	NXDN	0.26	WQGI994	453.6	AFM 2.5	FB2	6.25	53.87	0	0	-0.29	-1.09	-10.91
453.66875	NXDN	5.52	KCQ754	453.6625	AFM 2.5	FB2	6.25	67.3	0	0	-7.04	-2.52	-24.95
453.66875	NXDN	5.52	KBO824	453.675	AFM 5	FB	6.25	55.87	0	0.95	19.78	11.39	-24.95
453.66875	NXDN	5.52	WYX510	453.675	AFM 5	FB	6.25	54.49	0	1.63	13.09	5.99	-24.95
453.66875	NXDN	5.52	KYU718	453.675	AFM 5	FB	6.25	63.64	0	0	21.01	13.67	-24.95
453.66875	NXDN	5.52	WYX510	453.675	AFM 5	FB2	6.25	53.87	0.1	0.6	-0.29	-1.09	-24.95
453.66875	NXDN	5.52	WYX510	453.675	AFM 5	FB	6.25	53.87	0.1	0.6	-0.29	-1.09	-24.95
453.66875	NXDN	5.52	KCS433	453.675	AFM 5	FB2	6.25	50.9	5.26	6.75	-24.95	-20.82	-24.95
453.66875	NXDN	5.52	WQDP576	453.675	AFM 2.5	FB8	6.25	54.42	0	0	6.98	3.2	-24.95
453.78125	NXDN	2.32	WQLN768	453.775	AFM 5	FB2	6.25	70.16	0	0.35	13.26	11.82	-14.34
453.78125	NXDN	2.32	WPSH996	453.775	AFM 5	FB2	6.25	67.32	0	0.95	2.86	4.88	-14.34
453.78125	NXDN	2.32	WPNX520	453.775	AFM 5	FB8C	6.25	49.86	2.32	6.51	-14.34	-13.67	-14.34
453.78125	NXDN	2.32	WPNU570	453.7875	AFM 2.5	FB2	6.25	63.08	0	0	18.53	13.11	-14.34
460.05625	NXDN	0	WNYG437	460.05	AFM 5	FB2	6.25	59.85	0	1.65	3.24	2.98	-6.47
460.05625	NXDN	0	WQDP576	460.05	AFM 2.5	FB8	6.25	54.42	0	0	6.98	3.2	-6.47
460.05625	NXDN	0	KJJ516	460.0625	AFM 2.5	FB2	6.25	68.33	0	0	-6.47	-2.78	-6.47

Table 1: Proposed and incumbent radios, showing contour overlap and actual interference by percentage of area

These data represent incumbents ranging from approximately 42 kilometers to almost 80 kilometers. The case of co-location with a 6.25 kHz spaced incumbent, which could pass TSB-88, has unrelated disadvantages and was not considered for this paper.

The applicant, by its representative, has claimed that little interference would be created by the proposed system, despite contour overlap in all nine cases.

We have conducted extensive modeling of the proposed system, and generally agree that no substantial interference will be either caused or received on some of the frequencies. We argue (as we had during the discussion leading to the LMCC consensus) that the LMCC contour overlap requirements are too conservative, even when further derated by the agreed upon 3 dB which is set to occur on August 4, 2010.

To find a better balance between interference and spectrum efficiency based upon these data, consider the following:

- 1) The terrain underlying this study is quite typical for the CONUS, with the terrain roughness factor Δh approximately equal to 50 meters, upon which assumption the Longley-Rice model used in this analysis was based. Interference in flatter places would correspond better to the contour model, while standard deviation of interference probabilities increases geometrically with increased roughness.
- 2) Some interference (mostly to wideband analog incumbents) is present without contour overlap, though none reaches the 5% criterion as the largest is 3.68%.
- 3) There are many cases of contour overlap where little or no interference is predicted. Though not presented here, this remains true with the relaxed 39/32 dB μ V/m contour overlap method due to take effect 8/4/2010--all nine cases still have overlap
- 4) There were several incumbents very close geographically at 18.75 kHz frequency separation, but no interference was found (as expected) and these cases are not listed.
- 5) There are no incumbent NXDN or DMR (MotoTRBO) records, and no co-channel cases represented in this example. Since we routinely calculate interference in both directions, the data do illustrate AFM proposals in the presence of NXDN incumbents.
- 6) The Adjacent Channel Power Ratios, integrated over the data from TSB-88.C for these data are:

Modulation	ACPR to	ACPR from
AFM 5	13.81	3.14
AFM 2.5	29.93	33.88
EDACS-NB	25.31	57.54
C4FM	27.92	57.06

Table 2: ACPR Values in dB

These ratios range from 3 dB to 57.5 dB, yet all are represented by LMCC with a single contour-based ratio method. To compare the 10 dB LMCC ratio with these data, add the 14 dB conversion factor at UHF from F(50,50) to F(50,10), which yields a comparable LMCC value of 24 dB. This ratio underprotects wideband analog by >20 dB, and overprotects narrowband digital modulation types

(the two-slot DMR TDMA employed by Motorola enjoys even better protection than these) by more than 30 dB even after the forthcoming 3

dB adjustment. We argue that the benefit of "one-size-fits-all" simplicity is far outweighed by this cost. We note here that both the integral used to derive these ACPR values, and the asymmetry of the data in the TSB-88 bins will yield slightly differing numbers, in most cases less than one tenth of a decibel. For example, the figure for a narrowband analog coupling into an NXDN system is given as 29.93 dB for the lower adjacent--it is 29.95 dB for the upper adjacent incumbent.

To further put these data in perspective, consider two 100 watt ERP stations at 6.25 kHz frequency separation, one NDXN and one P25 (C4FM). The equivalent power for the NXDN system as a co-channel interferer would be 0.16 watts (16 milliwatts), and for the P25 system as victim only 0.0002 watts, comparable to that allowed everywhere for Part 15 devices. Clearly, NXDN systems in this adjacency do not require any protection

Contours or Tiles?

As may readily be seen in Table 1, even in comparatively gentle terrain there is a large disparity between contour overlap and actual interference, so no simple adjustment of contours such as derating, or even re-charting them based upon empirical data, could both adequately prevent interference and remain spectrum efficient. With increasing terrain roughness, as in the Appalachians or out West, this disparity dramatically increases. In the three West coast states, we estimate that the current contour-based protection method leaves over 50% of available narrowband spectrum fallow, and much of that is in areas with the highest demand. A tiled model better representing actual fields may be less intuitive, require software and if identical results are to be obtained by various engineers, careful attention to standardizing both methods and supporting data (tile size, terrain databases, use of clutter, masking and threshold criteria, to name a few). This was the intent, largely realized, in creating TSB-88, but that document presents several alternative choices among which a standard would have to be agreed upon. If the derating of contours is to be adopted as a standard protocol, a simplified proposal based on Adjacent Channel Power Ratio ("ACPR") generated from data in TSB-88.C is presented as Appendix C.

Composite Interference

We also wish to consider the issue of many-to-one interference caused to the proponent from all incumbents. Historically, coordinators have only considered interference to the incumbent, and that only on a one-to-one basis. We believe however, with some caution, a standard for many-to-one interference to a proponent may be calculated, and a limit imposed for trunked use--mimicking the DTV transition standard from Part 73, we propose 10%, but of area, rather than population served. TSB-88 specifies the "Equivalent Interference" method for combining fields from multiple incumbents. Generally, a value of 10% from all incumbents has proven satisfactory, but one must be careful which incumbents are included. For example, for two cases of proposed frequencies, all three of WPGS835 modulation types are included, and should not be. Instead, only the worst case modulation type for a facility which actually uses several should be added into the total.

The equivalent interference method is particularly sensitive to multiple similar interferers. Following only the 10% composite criterion, all nine frequencies in our example pass.

Mobile-only protection (outbound)

Mobile-only system protection has been the subject of considerable debate, and many of the methods used have unfortunately assumed hypothetical mobiles at the edge of an area on the radial between proposed and protected systems. What is even less justifiable, these hypothetical mobiles are sometimes assigned a service contour, as if such an area could represent the possible location of the "other protected mobile" with which communication was desired. This service contour method has the dual disadvantage of stretching the contour charts well below their 30 meter minimum HAAT value and protecting mobiles in an area beyond the claimed protected mobile area of operation ("AOP"). To arrive at a method which better protects actual use, and for which protection is based on actual proposed mobile operation, three assumptions must be made:

- 1) mobile-only protection should include only the AOP;
- 2) the protected AOP, when not jurisdictional (city, county or state, for example), should be limited to 40 kilometers at VHF and 32 kilometers at UHF; and
- 3) if the proposed paired trunked system is protecting an incumbent mobile-only from its mobiles on the talk-back channel, that the interfering contour of the proposed base station would over-protect the incumbent system.

A proposed trunked base station protecting a mobile-only system would do so adequately by its interfering contour (19/21 dBμ F(50,10) or 8/7 dBμ F(50,50) for VHF/UHF respectively). We have assessed the impact of mobile "talk-around" use of the base station channel, and find that in all cases where the base station is at least 30m AGL and its ERP is equal to or greater than the proposed paired mobile the average mobile interference area does not exceed that of the base station. In the case where the proposed mobile ERP exceeds that of the proposed base station, the system must be considered as interfering both as base and mobile as described below: it must protect the incumbent mobile-only AOP with both its base station interfering contour and its proposed AOP separated by a "Buffer area".

In order to account for the variation of ERP of the proposed trunked mobiles when protecting mobile-to-mobile, a buffering radius must be created between the proposed and protected AOP. A harmful interfering field to a 2m AGL mobile incumbent is created by a 2m AGL proposed mobile at approximately

VHF: 20 kilometers (100 watts), 14 kilometers (25 watts) and 10 kilometers (5 watts).

UHF: 25 kilometers (100 watts), 20 kilometers (25 watts) and 14 kilometers (5 watts).

We thus propose a that new trunked mobile AOP should be separated from the incumbent AOP by 10/14 kilometers for mobiles of five watts or less, by 14/20 kilometers from proposed mobiles of 5.1 to 25 watts, and by 20/25 kilometers for proposed mobiles of greater than 25 watts and VHF/UHF respectively. We recognize that not all mobiles fit into these classifications--Ambulances and Utility Line Trucks often have >3m AGL antennas, and hand-held portable radios often have inefficiencies due to antenna loading, lack of ground plane and local clutter, and are often operated at less than 2m AGL. Nevertheless, due to the inherently statistical nature of mobile operation, we find this buffer area to afford sufficient protection without overly restricting new proposals.

Mobile (inbound) Interference

Since both proposed and incumbent mobiles may be anywhere, inbound interference, which is by far the most common kind, is necessarily a statistical solution. Here we apply TSB-88 in a reverse method, and for each proposed mobile location we compare the field received by the protected base station receive antenna from that location to all possible locations within the incumbent area of operation. Those not meeting the required DAQ (C/I ratio), as modified by the ACPR, fail and are compared against the entire incumbent area, less tiles not receiving service, to arrive at a percentage. Since mobiles are randomly located for both proponent and incumbent, we have chosen 50% as an appropriate failure criterion for a single proposed tile, and the usual 5% for an overall failure rate.

This method includes the ERP of both mobile systems and the height of the base station receive antenna.

In our example in Logan County, the worst case of outbound interference, with more than 5% both caused and received, is 453.66875 proposed against KCS433, a wideband analog system at 50.9 kilometers distance. This combination would already be disallowed under existing criteria for outbound service and interference, and likewise fails the mobile interference test. This scenario is plotted as Figure 1.

In figure 2, the difference is clearly visible, as we present the worst case among the five frequencies not subject to any outbound interference over 5%. This is the proposed 453.34375 against KJQ831, which has two locations and is predicted to receive 3.68% at Location 1 and 0.94% at Location 3 respectively (Location #@ is their mobile facility). Curiously, there is LMCC method contour overlap only with Location #3, though less outbound interference is predicted. In Figure 2 (Location 1), less than 2% of the proposed mobile tiles within Logan County will cause appreciable interference to KJQ831, and when using KJQ831 Location 3 the figure is less than 1%.

While generalizing about inbound performance and interference from this one case is unwise, it is clear that this method much more closely mirrors the traditional outbound understanding. Since it employs the ACPR values derived from TSB-88, it can successfully navigate all possible frequency spacings and all modulation types reported to the TIA and made a part of their standard.

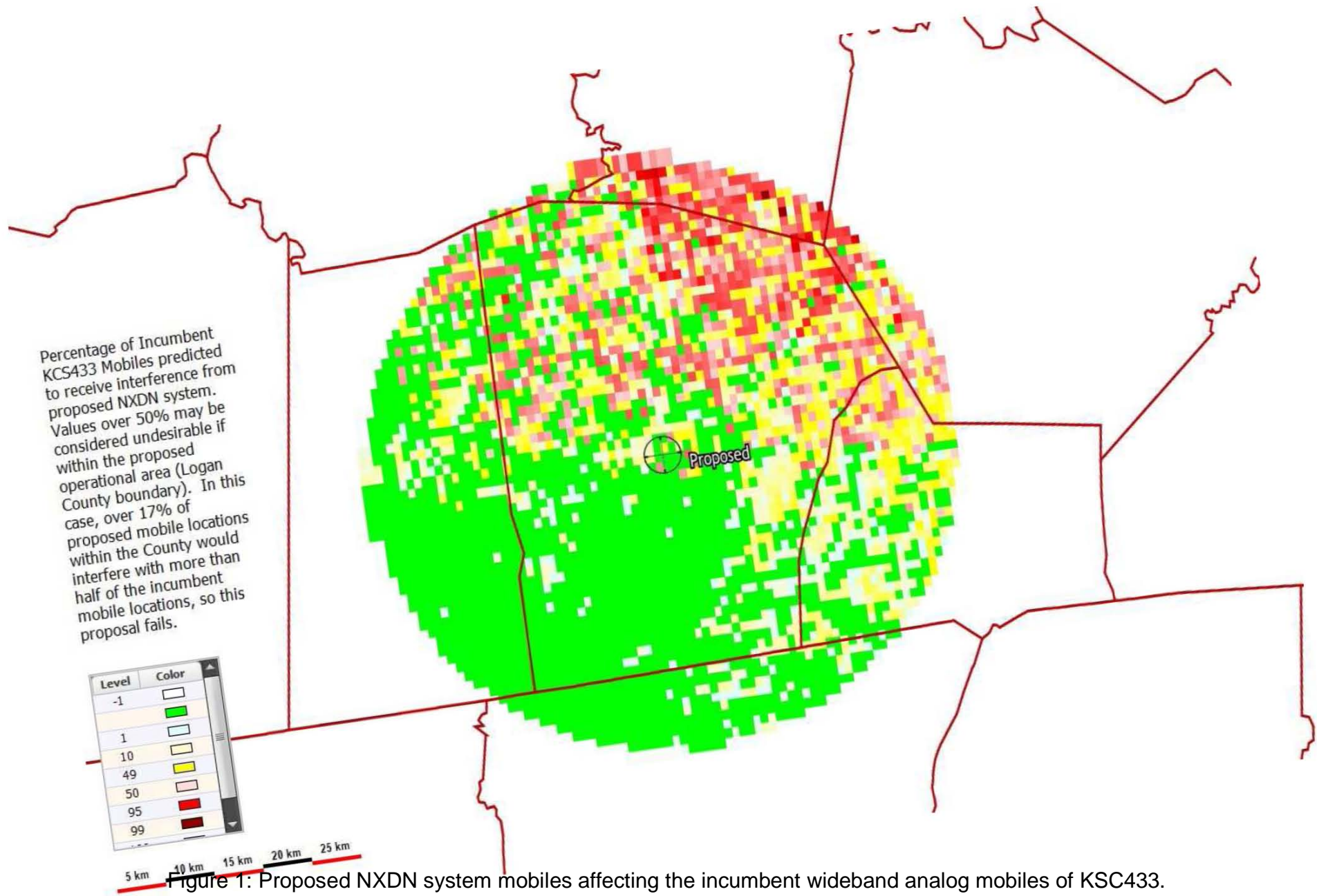


Figure 1: Proposed NXDN system mobiles affecting the incumbent wideband analog mobiles of KSC433.

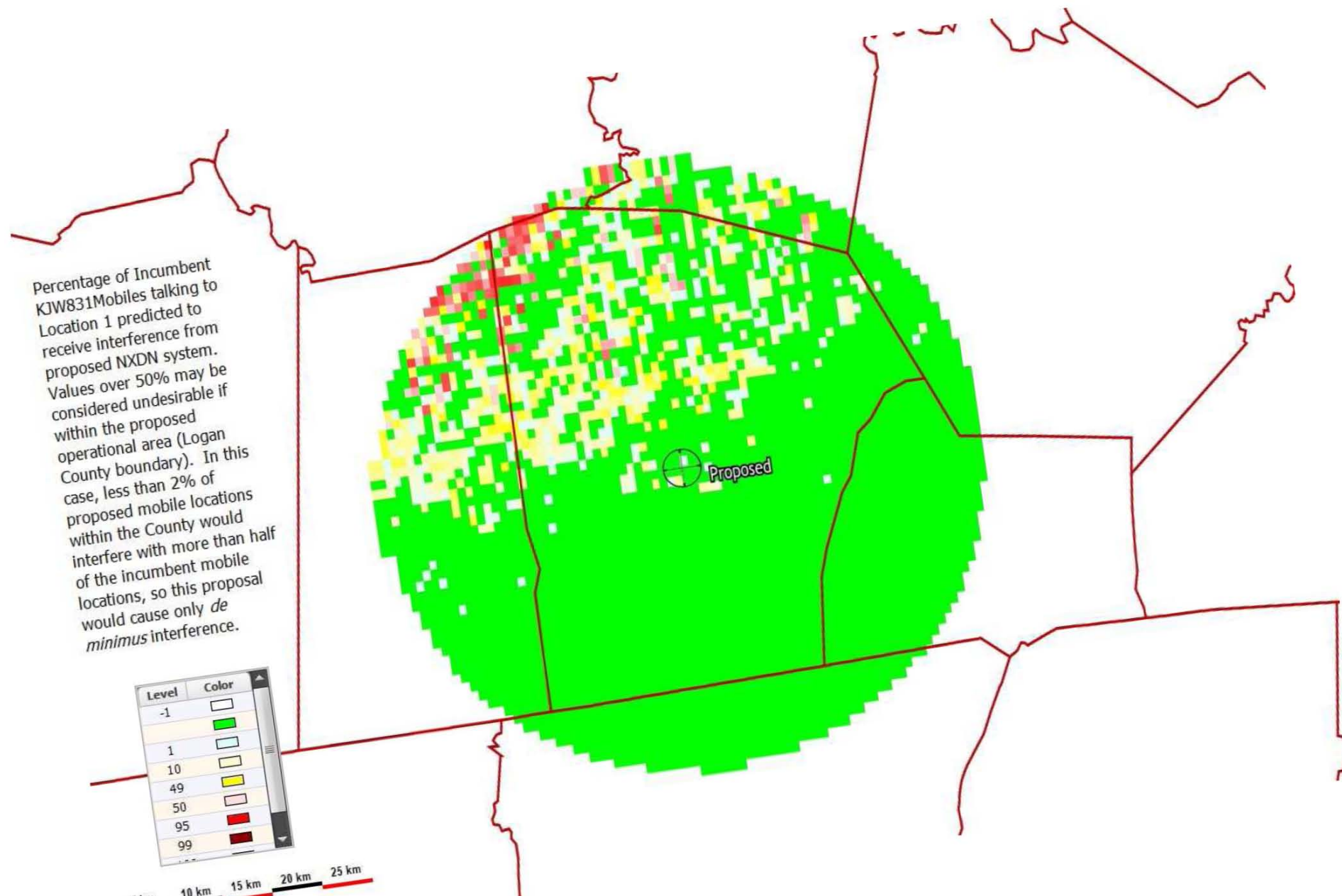


Figure 2: Proposed NXDN system mobiles affecting the incumbent wideband analog mobiles of KJQ831, Location 1.

Other Considerations

This paper is prepared with a neutral attitude to all modulation types. Wideband Analog, which will sunset in 2012 and can only be allocated for the remainder of this year, is treated the same as the highly efficient DMR and NXDN technologies. Should the current presumption from §90.187 that more spectrum-efficient modulation types should be encouraged, percentages other than five could easily be agreed upon. For example, in this case, allowing 10% interference to wideband incumbents would permit licensing of three of the four questionable frequencies at little cost in increased interference. Given the mobile-to-base interference from Figure 1, one might wish to limit the proposed mobiles to 25 watts, rather than the current case of 50 watts.

The allocation policies suggested here assume comparatively large service radii, 40 kilometers at VHF and 32 at UHF. If instead a cellular approach is used, where frequency reuse is multiplied by placing cells with differing frequency sets over the areas of co-channel interference, the ten percent composite interference limit suggested here must be reconsidered, as the interference area becomes spread into tiny areas and more evenly dispersed. In such a scenario, assumptions that two NXDN channels spaced at 6.25 kHz or two MotoTRBO channels spaced at 12.5 kHz may be independently assigned are not necessarily true.

Loading, or the number of mobiles which can share a channel, is also not discussed here, though it is a requirement for exclusive use (PSA) in the 470-512 MHz band in the eleven metropolitan areas where it is available, and in some of the 800 MHz band allocation policies. Smart radios will make loading more statistical and even less certifiable, but it remains a useful deterrent of spectrum hoarding.

Conclusion

There are in this paper three policy shifts: using a real-world (TSB-88 rather than contours) interference method, using occupied width (the specific modulation types rather than the channel bandwidth) and the consideration of mobile-to-base interference, a necessarily statistical approach. The unprecedented coincidence of narrowbanding and the advent of pervasive digital modulation offers both a justification and a mandate if spectrum efficiency is to be achieved and maintained as technology evolves. That the vast majority of legal opinion is in Portrait format is no reason to ignore the beckoning Landscape of technological opportunity.

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Appendix A: the Current Rule

FCC Trunking Rule, §90.187 (2009 Edition)

§ 90.187 Trunking in the bands between 150 and 512 MHz.

(a) Applicants for trunked systems operating on frequencies between 150 and 512 MHz (except 220–222 MHz) must indicate on their applications (class of station code, instructions for FCC Form 601) that their system will be trunked. Licensees of stations that are not trunked, may trunk their systems only after modifying their license (see § 1.927 of this chapter).

(b) Trunked systems operating under this section must employ equipment that prevents transmission on a trunked frequency if a signal from another system is present on that frequency. The level of monitoring must be sufficient to avoid causing harmful interference to other systems. However, this monitoring requirement does not apply if the conditions in paragraph (b)(1) or (b)(2) of this section, are met:

(1) Where applicants for or licensees operating in the 470–512 MHz band meet the loading requirements of § 90.313 and have exclusive use of their frequencies in their service area.

(2) On frequencies where an applicant or licensee does not have an exclusive service area provided that all frequency coordination requirements are complied with and written consent is obtained from affected licensees using either the procedure set forth in paragraphs (b)(2)(i) and (b)(2)(ii) of this section (mileage separation) or the procedure set forth in paragraph (b)(2)(iii) of this section (protected contours).

(i) Affected licensees for the purposes of this section are licensees of stations that have assigned frequencies (base and mobile) that are 15 kHz or less removed from proposed stations that will operate with a 25 kHz channel bandwidth; stations that have assigned frequencies (base and mobile) that are 7.5 kHz or less removed from proposed stations that will operate with a 12.5 kHz bandwidth; or stations that have assigned frequencies (base and mobile) 3.75 kHz or less removed from proposed stations that will operate with a 6.25 kHz bandwidth.

(ii) Where such stations' service areas (37 dBu contour for stations in the 150–174 MHz band and 39 dBu contour for stations in the 421–512 MHz bands; see § 90.205) overlap a circle with radius 113 km (70 mi.) from the proposed base station.

(iii) In lieu of the mileage separation procedure set forth in paragraphs (b)(2)(i) and (b)(2)(ii) of this section, applicants for trunked facilities may obtain consent only from stations that would be subjected to objectionable interference from the trunked facilities. Objectionable interference will be considered to exist when the interference contour (19 dBu for VHF stations, 21 dBu for UHF stations) of a proposed trunked station would intersect the service contour (37 dBu for VHF stations, 39 dBu for UHF stations) of an existing station. The existing stations that must be considered in a contour overlap analysis are a function of the channel bandwidth of the proposed trunked station, as follows:

(A) For trunked stations proposing 25 kHz channel bandwidth: Existing co-channel stations and existing stations that have an operating frequency 15 kHz or less from the proposed trunked station.

(B) For trunked stations proposing 12.5 kHz channel bandwidth: Existing co-channel stations and existing stations that have an operating frequency 7.5 kHz or less from the proposed trunked station.

(C) For trunked stations proposing 6.25 kHz channel bandwidth: Existing co-channel stations and existing stations that have an operating frequency 3.75 kHz or less from the proposed trunked station.

(iv) The calculation of service and interference contours referenced in paragraph (b)(2)(iii) of this section shall be done using generally accepted engineering practices and standards which, for purposes of this section, shall presumptively be the practices and standards agreed to by a consensus of all certified frequency coordinators.

(v) The written consent from the licensees specified in paragraphs (b)(2)(i) and (b)(2)(ii) or (b)(2)(iii)(A), (b)(2)(iii)(B) and (b)(2)(iii)(C) of this section shall specifically state all terms agreed to by the parties and shall be signed by the parties. The written consent shall be maintained by the operator of the trunked station and be made available to the Commission upon request. The submission of a coordinated trunked application to the Commission shall include a certification from the applicant that written consent has been obtained from all licensees specified in paragraphs (b)(2)(i) and (b)(2)(ii) or (b)(2)(iii)(A), (b)(2)(iii)(B) and (b)(2)(iii)(C) of this section that the written consent documents encompass the complete understandings and agreements of the parties as to such consent; and that the terms and conditions thereof are consistent with the Commission's rules. Should a potential applicant disagree with a certified frequency coordinator's determination that objectionable interference exists with respect to a given channel or channels, that potential applicant may request the Commission to overturn the certified frequency coordinator's determination. In that event, the burden of proving by clear and convincing evidence that the certified frequency coordinator's determination is incorrect shall rest with the potential applicant. If a licensee has consented to the use of trunking, but later decides against the use of trunking, that licensee may request that the licensee(s) of the trunked system(s) cease the use of trunking. Should the trunked station(s) decline the licensee's request, the licensee may request a replacement channel from the Commission. A new applicant whose interference contour overlaps the service contour of a trunked licensee will be assigned the same

channel as the trunked licensee only if the trunked licensee consents in writing and a copy of the written consent is submitted to the certified frequency coordinator responsible for coordination of the application.

(c) Trunking of systems licensed on paging-only channels or licensed in the Radiolocation Service (subpart F) is not permitted.

(d) Potential applicants proposing trunked operation may file written notice with any certified frequency coordinator for the pool (Public Safety or Industrial/Business) in which the applicant proposes to operate. The notice shall specify the channels on which the potential trunked applicant proposes to operate and the proposed effective radiated power, antenna pattern, height above ground, height above average terrain and proposed channel bandwidth. On receipt of such a notice, the certified frequency coordinator shall notify all other certified frequency coordinators in the relevant pool within one business day. For a period of sixty days thereafter, no application will be accepted for coordination which specifies parameters that would result in objectionable interference to the channels specified in the notice. Potential applicants shall not file another notice for the same channels within 10 km (6.2 miles) of the same location unless six months shall have elapsed since the filing of the last such notice. Certified frequency coordinators shall return without action, any coordination request which violates the terms of this paragraph (d).

(e) No more than 10 channels for trunked operation in the Industrial/Business Pool may be applied for in a single application. Subsequent applications, limited to an additional 10 channels or fewer, must be accompanied by a certification, submitted to the certified frequency coordinator coordinating the application, that all of the applicant's existing channels authorized for trunked operation have been constructed and placed in operation. Certified frequency coordinators are authorized to require documentation in support of the applicant's certification that existing channels have been constructed and placed in operation. Applicants in the Public Safety Pool may request more than 10 channels at a single location provided that any application for more than 10 Public Safety Pool channels must be accompanied by a showing of sufficient need. The requirement for such a showing may be satisfied by submission of loading studies demonstrating that requested channels in excess of 10 will be loaded with 50 mobiles per channel within a five year period commencing with grant of the application.

(f) If a licensee authorized for trunked operation discontinues trunked operation for a period of 30 consecutive days, the licensee, within 7 days of the expiration of said 30 day period, shall file a conforming application for modification of license with the Commission. Upon grant of that application, new applicants may file for the same channel or channels notwithstanding the interference contour of the new applicant's proposed channel or channels overlaps the service contour of the station that was previously engaged in trunked operation.

Appendix B: Data using other protocol variables

We tested a number of variables other than those assumed for the results in the example used in this paper. We tried differing tile sizes, from 3 arc seconds through 15 arc seconds, and found no remarkable differences. Here is the data from a 6 arc second run:

Proposed			Incumbent						TSB-88C: DAQ = 3.0		Contour Overlap Clearance (LMCC Method)		
Frequency	Modulation	Ix Rec.	Callsign	Frequency	Modulation	Class	δF [kHz]	Dist. [km]	Ix To Proposed	Ix To Existing	Clr From	Clr To	Clr Total
453.19375	NXDN	0.01	WQHA642	453.1875	AFM 2.5	FB2	6.25	53.16	0	0	1.24	0.73	-5.96
453.19375	NXDN	0.01	WPZK721	453.2	AFM 2.5	FB8	6.25	50.46	0	0.02	-5.84	-5.96	-5.96
453.19375	NXDN	0.01	WQDP576	453.2	AFM 2.5	FB8	6.25	54.42	0	0	6.98	3.2	-5.96
453.26875	NXDN	0.35	WPSG835	453.2625	AFM 2.5	FB2	6.25	60.87	0.01	0	-13.34	-10.51	-13.34
453.26875	NXDN	0.35	WPSG835	453.2625	C4FM	FB2	6.25	60.87	0.08	0	-13.34	-10.51	-13.34
453.26875	NXDN	0.35	WPSG835	453.2625	EDACS-NB	FB2	6.25	60.87	0.02	0	-13.34	-10.51	-13.34
453.26875	NXDN	0.35	KEL335	453.275	EDACS-NB	FB2	6.25	69.36	0	0	16.7	14.08	-13.34
453.34375	NXDN	0.43	WPSG835	453.3375	AFM 2.5	FB2	6.25	60.87	0.01	0	-13.34	-10.51	-13.34
453.34375	NXDN	0.43	WPSG835	453.3375	C4FM	FB2	6.25	60.87	0.08	0	-13.34	-10.51	-13.34
453.34375	NXDN	0.43	WPSG835	453.3375	EDACS-NB	FB2	6.25	60.87	0.02	0	-13.34	-10.51	-13.34
453.34375	NXDN	0.43	KJQ831	453.35	AFM 5	FB	6.25	50.12	0	3.21	12	2.95	-13.34
453.34375	NXDN	0.43	KJQ831	453.35	AFM 5	FB2	6.25	48.28	0.04	1.05	4.37	-2.21	-13.34
453.34375	NXDN	0.43	WQA711	453.35	AFM 5	FB2	6.25	75.19	0	0.19	14.16	14.02	-13.34
453.34375	NXDN	0.43	WQDP576	453.35	AFM 2.5	FB8	6.25	52.3	0.02	0	1.73	-1.2	-13.34
453.39375	NXDN	8.09	WPQD283	453.3875	AFM 2.5	FB2	6.25	43.5	0.04	1.53	-16.39	-16.95	-24.89
453.39375	NXDN	8.09	KCQ735	453.3875	AFM 2.5	FB2	6.25	50.9	0.27	0.16	-24.89	-20.72	-24.89
453.39375	NXDN	8.09	WQD432	453.4	AFM 5	FB	6.25	41.92	4.74	4.18	-13.8	-12.68	-24.89
453.39375	NXDN	8.09	WPNX520	453.4	AFM 5	FB8C	6.25	49.86	2.83	5.47	-14.34	-13.67	-24.89
453.53125	NXDN	0.99	KIM774	453.525	AFM 5	FB2	6.25	55.74	0.97	6.36	-12.38	-9.52	-13.34
453.53125	NXDN	0.99	WQDP576	453.525	AFM 2.5	FB8	6.25	54.42	0	0	6.98	3.20	-13.34
453.53125	NXDN	0.99	WPSG835	453.5375	AFM 2.5	FB2	6.25	60.87	0.01	0.03	-13.34	-10.51	-13.34
453.59375	NXDN	0.35	WPWS449	453.5875	AFM 2.5	FB2	6.25	36.38	0	1.01	-1.8	-10.91	-10.91
453.59375	NXDN	0.35	KDX279	453.6	AFM 5	FB	6.25	73.7	0.11	0.3	-1.86	1.44	-10.91
453.59375	NXDN	0.35	KDX279	453.6	AFM 5	FB2	6.25	73.7	0.11	0.3	-1.86	1.44	-10.91
453.59375	NXDN	0.35	WQGI994	453.6	AFM 2.5	FB2	6.25	53.87	0	0	-0.29	-1.09	-10.91
453.66875	NXDN	5.13	KCQ754	453.6625	AFM 2.5	FB2	6.25	67.3	0.01	0	-7.04	-2.52	-24.95

453.66875	NXDN	5.13	KBO824	453.675	AFM 5	FB	6.25	55.87	0	1.62	19.78	11.39	-24.95
453.66875	NXDN	5.13	WYX510	453.675	AFM 5	FB	6.25	54.49	0	0.77	13.09	5.99	-24.95
453.66875	NXDN	5.13	KYU718	453.675	AFM 5	FB	6.25	63.64	0	0.77	21.01	13.67	-24.95
453.66875	NXDN	5.13	WYX510	453.675	AFM 5	FB2	6.25	53.87	0	0	-0.29	-1.09	-24.95
453.66875	NXDN	5.13	WYX510	453.675	AFM 5	FB	6.25	53.87	0.18	0.38	-0.29	-1.09	-24.95
453.66875	NXDN	5.13	KCS433	453.675	AFM 5	FB2	6.25	50.9	4.7	7.02	-24.95	-20.82	-24.95
453.66875	NXDN	5.13	WQDP576	453.675	AFM 2.5	FB8	6.25	54.42	0	0	6.98	3.2	-24.95
453.78125	NXDN	2.8	WQLN768	453.775	AFM 5	FB2	6.25	70.16	0	0.27	13.26	11.82	-14.34
453.78125	NXDN	2.8	WPSH996	453.775	AFM 5	FB2	6.25	67.32	0.04	0.98	2.86	4.88	-14.34
453.78125	NXDN	2.8	WPNX520	453.775	AFM 5	FB8C	6.25	49.86	2.75	5.79	-14.34	-13.67	-14.34
453.78125	NXDN	2.8	WPNU570	453.7875	AFM 2.5	FB2	6.25	63.08	0	0	18.53	13.11	-14.34
460.05625	NXDN	0.07	WNYG437	460.05	AFM 5	FB2	6.25	59.85	0.07	2.15	3.24	2.98	-6.47
460.05625	NXDN	0.07	WQDP576	460.05	AFM 2.5	FB8	6.25	54.42	0	0	6.98	3.2	-6.47
460.05625	NXDN	0.07	KJJ516	460.0625	AFM 2.5	FB2	6.25	68.33	0	0	-6.47	-2.78	-6.47

Table 3: Proposed and incumbent radios, showing actual interference by percentage of area over six arc second tiles.

One concern is for the very small service areas, which are poorly served by the larger 30 second (~ 1 kilometer) tile size. Here, observing KJQ831 where its location #1 is very low and appears to be at the dispatch station. we see an increase in Interference--and this despite the lack of contour overlap. It is these smaller systems which are the most vulnerable to generalization, be it contours or tile size, and allowance should be made for these types of systems. Figure 3 below gives a plot of the predicted interference. This is the same example used for mobile interference (M2B).

Appendix C: Suggested Simplified Contour Derating Values based on ACPR

7.5 kHz Spacing

	4K0	11K3	16K2	Wide data
Protected 4K0 or less	N/R	37	21	7
11K3 or less	N/R	21	11	6
16K2 or less	12	6	11	4
Wideband data	0	0	4	2

15 kHz Spacing

	4K0	11K3	16K2	Wide data
Protected 4K0 or less	N/R	N/R	N/R	N/R
11K3 or less	N/R	N/R	60	55
16K2 or less	N/R	N/R	39	20
Wideband data	N/R	40	21	7

6.25 kHz Spacing

	4K0	11K3	16K2	Wide data
Protected 4K0 or less	N/R	28	14	7
11K3 or less	40	14	5	5
16K2 or less	3	3	3	3
Wideband data	0	0	0	0

12.5 kHz Spacing

	4K0	11K3	16K2	Wide data
Protected 4K0 or less	N/R	N/R	54	52
11K3 or less	N/R	N/R	40	35
16K2 or less	N/R	41	23	8
Wideband data	53	19	10	5

Since the interference is not symmetrical between modulation types, the proposed system is along the top of the chart, and the protected type to the left. These values represent ratios, in decibels, with which to increase the value of interfering contours when adjacent channels are used. A derating ratio based on an ACPR above 60 dB was considered not to require (N/R) coordination, as the interfering area would always be very small. An argument could be made to allow values above 50 dB without coordination, but since these practically apply only to new proposed wideband analog systems which will be disallowed as of 1/1/2011, it is likely moot.

The case of proposed 4K0 interference to the various protected 11K3 systems at 6.25 kHz spacing had the largest standard deviation between modulation types, with narrowband analog at ~34 dB (compare Table 2) and the various digital types ranging from 36 to 57 dB, so the listed value of 40 somewhat underprotects analog narrowband systems.

These could of course be further simplified. One could list all derating ratios less than 10 dB as co-channel (zero), though that affects only 16K2 proponents and incumbents, and those might be better increased than decreased as refarming concludes.

In our Logan County example, using these proposed factors would remove all contour overlaps with refarmed (11K3 or less) incumbents, but would actually increase the overlaps with wideband analog incumbents, which constitute the majority. The 8 dB LMCC derating ratio (suggested by the undersigned) in the case of incumbent wideband analog was a compromise favoring digital modulation. Thus were the simplified ratios to be adopted, the example system, most of whose frequencies would not cause objectionable interference, would have to wait until 2013 unless all the incumbents were able to narrowband earlier and modified their licenses accordingly.

This paper is intended to be neutral about solutions, simply illustrating the options. It is our hope that Commenters and other interested parties will take the trouble to find data-driven solutions to adjacent channel and mobile-only interference, but one cannot help but observe that for a very average Public Safety application two and a half years, with dependent funding, is a long time to wait for a system which could be allowed immediately.